

RESEARCH ARTICLE

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OPTIMIZATION OF A NOVEL TORQUE SHARING FUNCTION FOR IMPROVED SWITCHED RELUCTANCE MOTOR CONTROL USING PSO

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ABSTRACT

Switched Reluctance Motors (SRMs) are increasingly adopted in modern electric drive systems due to their mechanical robustness, fault tolerance, and high efficiency. However, their nonlinear magnetic characteristics and discrete torque production often result in pronounced torque ripple, which can limit performance in precision applications. This paper introduces an enhanced optimization strategy for the Torque Sharing Function (TSF) to minimize torque ripple in SRMs. The TSF is essential for regulating instantaneous torque by distributing the reference torque among individual phases according to rotor position, thereby improving torque smoothness and operational stability. The proposed method divides the reference torque into multiple subintervals during phase excitation to control overlap duration and reduce negative torque during commutation. Key control parameters including turn-on, turn-off, and overlap angles are jointly optimized by particle swarm optimization algorithm (PSO) to achieve an effective balance between torque ripple reduction, efficiency, and performance across a wide speed range. Finite element analysis is employed for accurate magnetic characterization, while iterative optimization algorithms ensure consistency, convergence, and robustness. Simulation results validate the proposed framework, showing notable reductions in torque ripple, improved speed regulation, and enhanced dynamic response. The method provides a flexible and scalable control solution applicable to various SRM configurations, promoting advancements in high-performance electric drive systems.



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I. INTRODUCTION

Switched Reluctance Motors, characterized by their simple mechanical design and the use of non-wound, salient rotor structures, have become increasingly attractive in modern electric drive applications. Their absence of rotor windings or permanent magnets significantly reduces manufacturing cost and enhances reliability, enabling consistent operation under harsh thermal and mechanical environments. Torque is generated by the inherent magnetic tendency of rotor poles to align with energized stator poles, resulting in a robust and durable electromagnetic drive mechanism suitable for industrial, automotive, and aerospace applications [1]. Despite these benefits, SRMs are hindered by a fundamental performance limitation: high torque ripple. The doubly salient structure, concentrated stator windings, and inherent discontinuous excitation result in large fluctuations in instantaneous torque, often leading to vibration, acoustic noise, and degraded dynamic behavior. These effects are generally more pronounced than in conventional induction or synchronous machines, where smoother electromagnetic torque generation is possible.

Although motor-level improvements, such as refined magnetic circuit design, can partially mitigate this issue, substantial ripple reduction is most effectively achieved through advanced control strategies implemented at the power converter and drive level [1], [2]. Unlike conventional machines that frequently rely on model-based approaches such as field-oriented control, SRM drives are well-suited to real-time, analytically derived, position-dependent current control schemes. This flexibility has led to the development of a diverse range of torque control techniques from basic commutation strategies to computationally adaptive schemes capable of enhancing torque smoothness without requiring structural modifications to the machine [1], [3]. Among these strategies, the Torque Sharing Function has emerged as a central approach for ripple suppression. TSF-based control distributes the total torque reference among the active phases such that the resulting composite torque waveform achieves reduced variation over a full electrical cycle. Early TSF designs employed fixed torque profiles and uniform turn-on angle staggering, providing noticeable ripple reduction but sacrificing copper loss efficiency due to suboptimal current shaping. Subsequent developments introduced adaptive weighting functions that dynamically modify each phase's torque contribution, achieving torque error below 1% and limiting ripple to under 3%, markedly outperforming traditional direct torque control methods, which commonly yield ripples in the range of 15% [4]. More advanced formulations have decoupled the TSF reference waveform from phase excitation timing, allowing excitation angles to be independently optimized in real time for further ripple reduction without altering the total torque reference [5].

Hybrid approaches combining TSF with methods such as super-twisting sliding-mode control have also demonstrated improved robustness, reduced chattering, and greater suitability for demanding applications such as electric vehicle propulsion [6]. While, in [7], a torque ripple reduction strategy for Doubly Salient Electromagnetic Machines (DSEM) is proposed based on the use of Current Given Functions (CGFs). By systematically selecting suitable CGFs and corresponding overlap angles for varying operating conditions, the method enhances current tracking accuracy and improves the torque–ampere ratio. Multiple CGF profiles including linear, cubic, cosine, and exponential functions are evaluated to optimize current distribution during commutation, thereby reducing both torque ripple and copper losses. Furthermore, a modified piecewise Torque Sharing Function described in [8] achieves additional ripple suppression during phase transitions, while model predictive control further attenuates ripple caused by hysteresis-based current regulation. This combined approach streamlines the optimization process by computing phase current trajectories directly as a function of rotor position via the TSF, eliminating the need to manually assign weighting factors in the control cost function. These contributions illustrate a clear progression in TSF methodologies from early static angle-staggering approaches to increasingly dynamic, efficiency-focused, and model-based control frameworks. Each generation of techniques has contributed incremental improvements in torque ripple suppression while simultaneously balancing key considerations such as computational complexity, real-time feasibility, and electromagnetic efficiency. Therefore, this paper introduces a new hyperbolic TSF formulation to further enhance the smoothness of torque transition between outgoing and incoming phases.

Unlike conventional TSFs that rely primarily on turn-on, turn-off, and fixed overlap angles, the proposed method presents hyperbolic shaping coefficients that allow finer control of phase current evolution during commutation. This approach improves torque continuity, suppresses negative torque, and enhances overall drive efficiency. A Particle Swarm Optimization (PSO) algorithm is utilized to automatically tune commutation parameters by jointly optimizing multiple objectives, including torque ripple reduction, copper loss minimization, and electromagnetic smoothness. The proposed method is integrated into a complete control framework and evaluated using a high-fidelity nonlinear finite element model of an 8/6 SRM. Comparative simulation results confirm that the optimized hyperbolic TSF significantly outperforms conventional and non-optimized strategies, offering improved dynamic response, smoother torque profiles, and enhanced overall suitability for high-performance electric drive systems. Within this scope, the present work advances an optimized Torque Sharing Function (TSF) control methodology engineered to substantially mitigate torque ripple and ameliorate the associated spectral attributes of vibration and acoustic noise. The validity of the proposed approach is established through a multi-faceted validation framework incorporating analytical, finite element (FEA), and dynamic system simulations. Thus, the paper proceeds with the following organization: Section II covers the fundamental modelling and electromagnetic equations of the Switched Reluctance Motor. Section III discusses outcomes from finite element modelling, including flux distribution. Section IV elaborates on the Torque Sharing Function control strategy, introducing the novel optimized method. Concluding in Section V, the results are presented and discussed, with a thorough assessment of the strategy's effectiveness in reducing torque ripple.

II. MODELLING OF 8/6 SRM

II.1 FINITE ELEMENT MODELLING

The finite element method (FEM) stands out as a powerful numerical technique for solving electromagnetic field problems, especially when confronted with intricate geometries and pronounced material nonlinearities, as commonly found in switched reluctance machines [9], [10]. To precisely model these complex features, the Ansys Maxwell environment was utilized, incorporating detailed geometric parameters along with a customized automated APDL (ANSYS Parametric Design Language) script specifically designed for the 6/8 SRM configuration under investigation. This integrated approach facilitates efficient, high-fidelity modelling and simulation, delivering accurate and dependable electromagnetic performance results [11] as showing in figure (1).

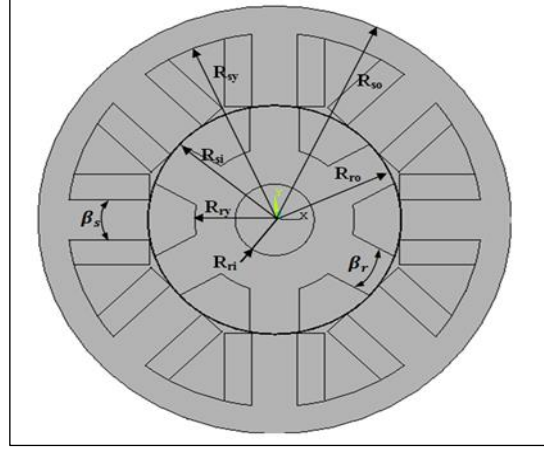


Figure 1: SRM Prototype Dimensions Specification.
Souce: Authors, (2026).

In addition, the details of dimensions and electrical parameters are shown on appendix table (1).

II.2 SIMULATION AND FLUX DISTRIBUTION

The electromagnetic field distribution in the SRM is shaped by the magnetic vector potential as well as the nonlinear permeability of the magnetic material [12].

$$\text{curl}(\nu \text{curl}(\vec{A})) = \vec{J} \quad (1)$$

Where ν denotes the magnetic reluctivity and represents the source current density vector. For the case of Cartesian coordinates, this yields:

$$\frac{\partial}{\partial x} \left(\nu \frac{dA_z}{dx} \right) + \frac{\partial}{\partial y} \left(\nu \frac{dA_z}{dy} \right) = -J_z \quad (2)$$

The flux linkage for a single operational step of the motor is determined from the resulting distribution of the magnetic vector potential:

$$\phi = \frac{1}{i} \int_V \vec{J} \vec{A} dV \quad (3)$$

After determining the relevant elements along the machine's axial length, the number of turns per phase, N , is defined in (7), and the winding area for each phase is denoted as S .

$$\phi = \frac{NI}{S} \sum_{k=1}^N (A_k S_k) \quad (4)$$

The inductance and magnetic co-energy are determined as functions of the flux linkage using the expressions given below:

$$L(\theta, i) = \frac{\phi(\theta, i)}{i} \quad (5)$$

$$W_{em} = \int_0^i \phi(\theta, i) di \quad \theta = \text{Const} \quad (6)$$

Using the co-energy approach, the electromagnetic torque is computed as the partial derivative of the magnetic co-energy with respect to the rotor angular position, while keeping the phase current constant, as given by the following equation:

$$T(\theta, i) = \frac{\partial W_{em}}{\partial \theta} \bigg|_{\theta = \text{Cons}} \quad (7)$$

Figure 2 presents both graphical and quantitative representations of the magnetic flux density distribution within the 6/8 SRM, with a phase current of 2 A and 12A applied. These results validate the machine's anisotropic inductance profile, a fundamental characteristic for torque production in SRMs. The numerical output further supports subsequent analysis, such as inductance profiling and torque estimation, essential for control strategy development. Figures 3 and 4 show, respectively, the numerical characteristics of the inductance and the static torque are evaluated as functions of the rotor position, first from the aligned to the non-aligned position and then from the non-aligned back to the aligned position. The results are presented for phase currents ranging from 2 A to 16 A. The results illustrate the extent of magnetic saturation in the machine, showing that increasing the current yields progressively larger saturation at higher current levels. By leveraging the previously captured characteristics, the model more accurately represents real-machine behavior and, depending on the formulation adopted, can provide robust results for control design and validation in journal-quality studies [13].

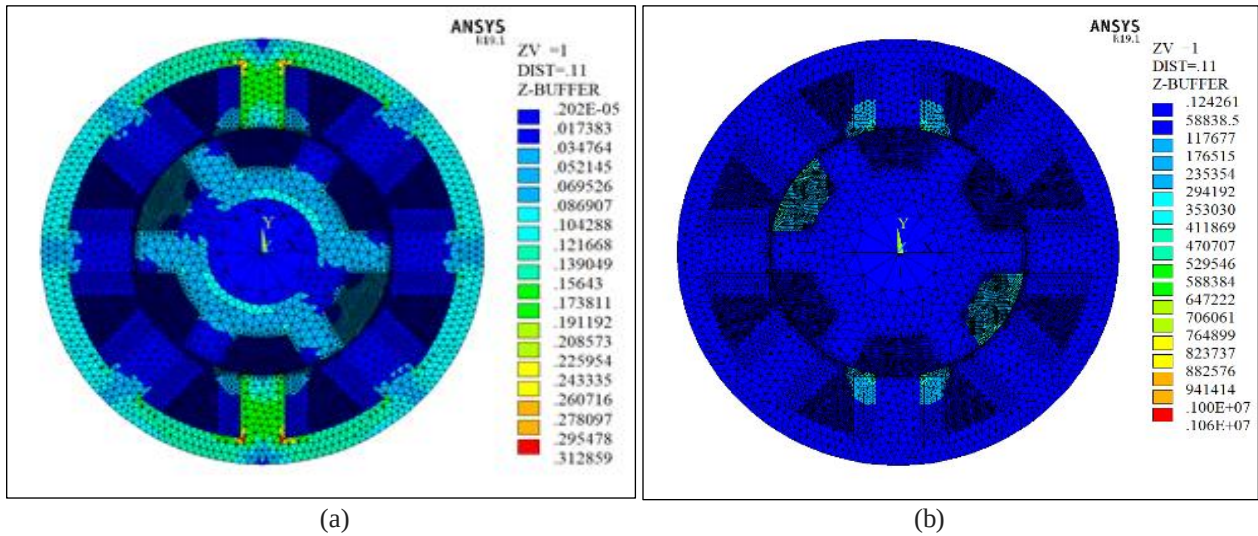


Figure 2: Flux density of 8/6 SRM for a current: (a) 2 A, (b) 12A.
Source: Authors, (2026).

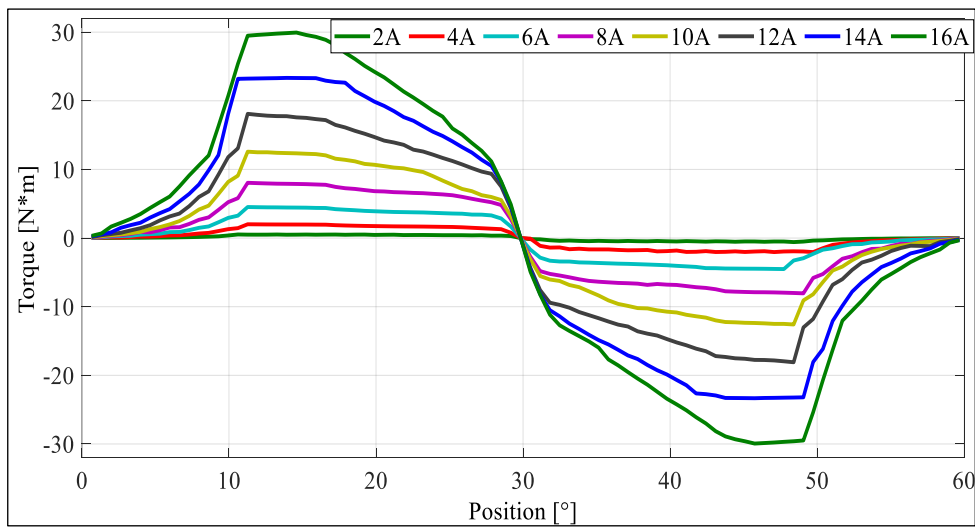


Figure 3: Static torque characteristics as a function of rotor position for phase currents between 2 A and 16 A.
Source: Authors, (2026).

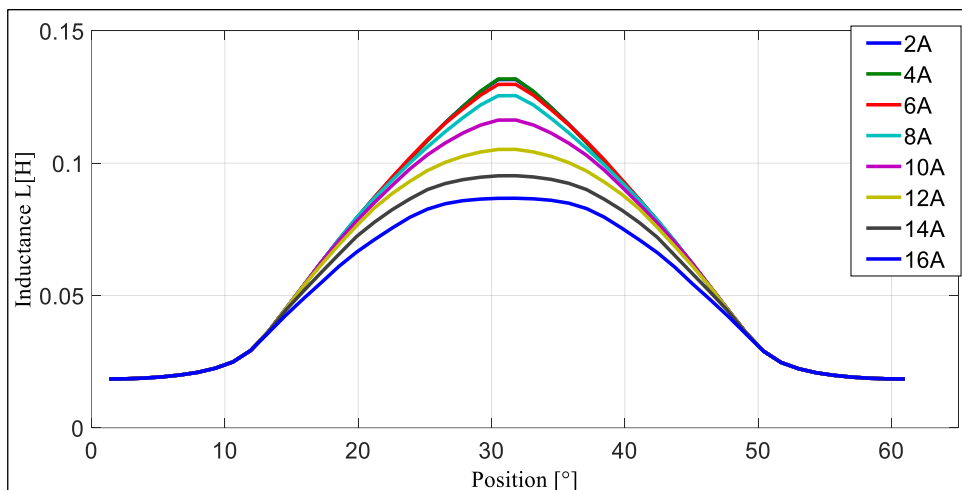


Figure 4: Inductance characteristics as a function of rotor position for phase currents between 2 A and 16 A.
Source: Authors, (2026).

The results illustrate the extent of magnetic saturation in the machine, showing that increasing the current yields progressively larger saturation at higher current levels. By leveraging the previously captured characteristics, the model more accurately represents real-machine behavior and, depending on the formulation adopted, can provide robust results for control design and validation in journal-quality studies [13]. To illustrate the modelling of the 6/8 SRM, a comprehensive schematic of the associated asymmetric bridge converter is presented in figure 5.

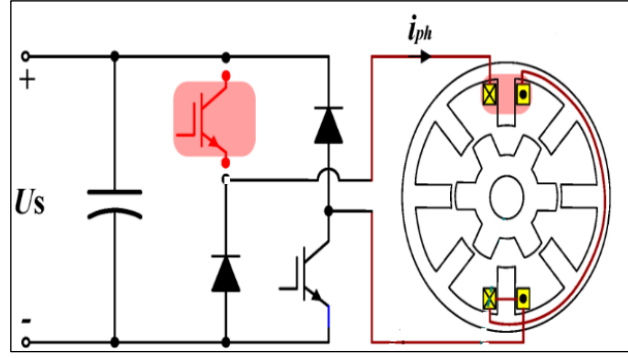


Figure 5: Overview of the 6/8 SRM and its associated asymmetric bridge converter.
Source: Authors, (2026).

The converter topologies of Asymmetric bridge / half bridge (per phase) Feature Two switches/diodes per phase enabling bidirectional current control and independent commutation; widely used with angle control and soft chopping methods [14], [15]. The regulation of an engine constitutes a complex undertaking that calls for the capabilities of adept specialists. Each procedural step is managed independently through the utilization of a hysteresis controller or Pulse Width Modulation (PWM) control. The majority of applications employ an unbalanced bridge configuration to govern the current within the defined hysteresis limits. This asymmetric bridge configuration facilitates three distinct voltage states: $+V_{cc}$ positive, 0 zero, and $-V_{cc}$ negative. Consequently, contingent upon the selected control methodology, all of these voltage states are employed to regulate the variable reluctance machine [12]. When a half-bridge converter is used to supply the motor with a hysteresis current controller, a significant negative current change occurs abruptly due to the reversal of voltage polarity across the machine windings. This effect induces vibrations of considerable amplitude [16]. To mitigate this issue, the present study adopts a methodology based on two-step commutation (2sc). Thus, the principle of the methodology is as follows: During the transition phase, the voltage initially applied to phase 1 is at its positive level, corresponding to the DC bus voltage, $V = +V_{dc}$. It then decreases to zero and, after a duration approximately equal to half the resonance cycle, rises to its negative level when the switches open and diodes D1 and D2 conduct. At this point, the applied voltage is reversed to $V = -V_{dc}$ and remains in this state until the current drops to zero. This approach effectively reduces both vibrations and acoustic noise in the machine [17].

III. MATHEMATICAL EQUATION

For a switched reluctance motor, the dynamic system refers to a phase winding which can be modelled as an inductance in series with a resistance, as shown in the figure 6 [13].

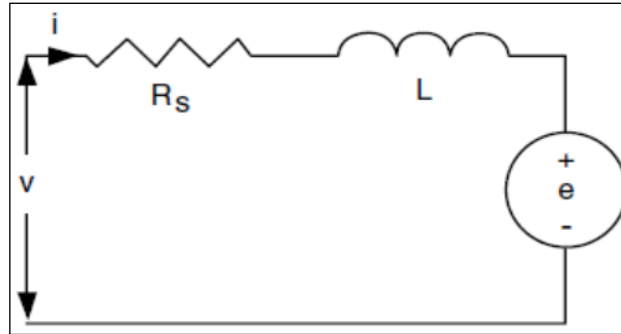


Figure 6: equivalent circuit of one of SRM.
Source: Authors, (2026).

The electromagnetic equation of the model is then written as [11]:

$$V = R_s i_j + \frac{d\Phi_j(\theta, i)}{dt} : j = 1, 2, 3, 4 \quad (8)$$

Where R_s and Φ_j are respectively, the resistance and the flux linkage per phase. j indicates the order of the phases. The flux linkage of the SRM is expressed as a function of the inductance characteristic $L(\theta, i)$ by the following equation:

$$\Phi(\theta, i) = L(\theta, i) \cdot i \quad (9)$$

The inductance $L(\theta, i)$ depends on both the rotor position and the phase current. Consequently, the phase voltage is determined using Equations (1) and (2):

$$V = R_s \cdot i_j + L(\theta, i) \cdot \frac{di}{dt} + \frac{dL(\theta, i)}{d\theta} \cdot i_j \cdot \frac{d\theta}{dt} \quad (10)$$

The back electromotive force $E_f(\theta, i)$ is given by:

$$E_f(\theta, i) = \frac{dL(\theta, i)}{d\theta} \cdot i \cdot \omega \quad (11)$$

Furthermore, the mechanical dynamics play a crucial role in electromechanical machines [18], [19]. The mechanical model can be expressed as follows:

$$T_e(\theta, i) = T_m(\theta, i) + f \cdot \omega + j \cdot \frac{d\omega}{d\theta} \quad (12)$$

The parameter j denotes the moment of inertia, ω represents the rotor speed, f is the friction coefficient, and T_m corresponds to the load torque. The electromagnetic torque $T_e(\theta, i)$ is determined from:

$$T_{ej}(\theta, i) = \frac{1}{2} \cdot i^2 \cdot \frac{dL(\theta, i)}{d\theta} : j = 1, 2, 3, 4 \quad (13)$$

Where $L(\theta, i)$ denotes the inductance, i represents the total current and R is the phase resistance. Supplying the machine during either the increasing or decreasing inductance region determines the operating mode, as illustrated in Figure 7 [12]. Motor mode ($T_e > 0$) occurs during the rising inductance region ($\partial L / \partial \theta > 0$). Generator mode ($T_e < 0$) occurs during the falling inductance region ($\partial L / \partial \theta < 0$).

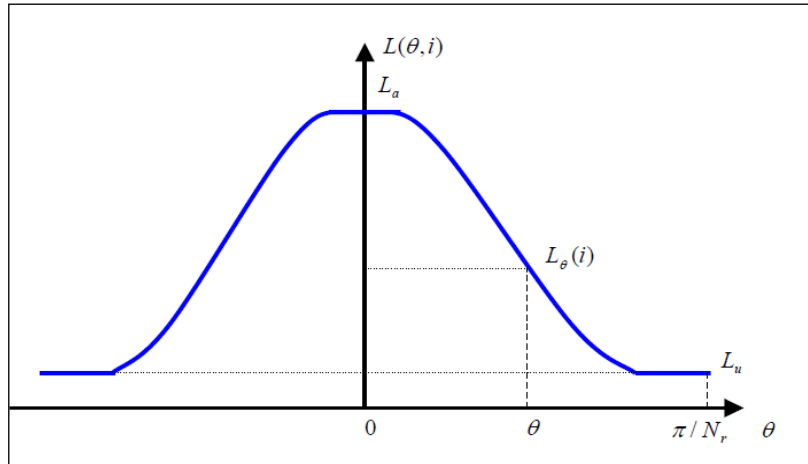


Figure 7: Principle of operation of the SRM.

Source: Authors, (2026).

IV. TORQUE SHARING FUNCTION-BASED CONTROL STRATEGY

The block diagram of the direct instantaneous torque control strategy for the SRM is shown in Figure 8. The torque closed-loop architecture consists of a torque computation unit, a hysteresis controller, a power converter, the switched reluctance motor (SRM), a position sensor, and a current sensor. The total reference torque, T_{ref} , is distributed into phase-specific reference torques, T_{kref} , at discrete rotor positions according to a torque-sharing function. The instantaneous output torque is obtained from a lookup table, and the torque error ($T_{ref} - T_{out}$) is processed by the torque hysteresis controller to generate the gating signals for the power converter. The torque-sharing function defines the overall control strategy, ensuring coordinated and high-precision torque production [20].

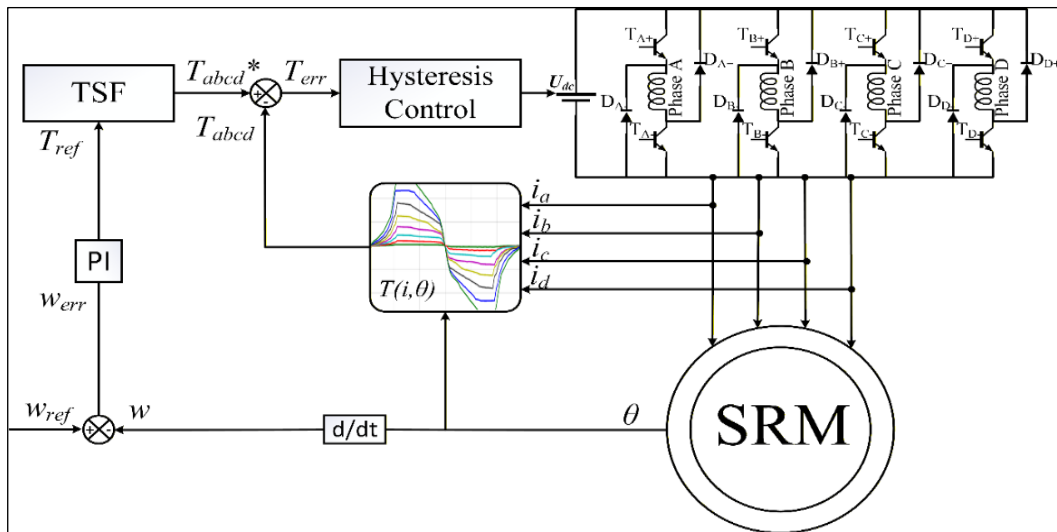


Figure 8: Control block diagram of the SRM based on the TSF strategy.

Source: Authors, (2026).

To ensure the control objective of the Torque Sharing Function (TSF) based on the synthesized instantaneous torque, the following equation must be satisfied for the SRM [20].

$$\begin{cases} T_k(\theta) = T^* f_k(\theta), k = 1, 2, \dots, m, \\ \sum_{k=1}^m f_k(\theta) = 1, 0 \leq f_k(\theta) \leq 1 \end{cases} \quad (14)$$

Where $T_k(\theta)$ represents the instantaneous torque of the k-th phase winding, T^* denotes the synthesized instantaneous reference torque, and $f_k(\theta)$ corresponds the torque-sharing function of the k-th phase winding. The TSF directly regulates the peak current of each machine phase, thereby influencing torque ripple and ensuring stable steady-state operation. The fundamental principle of the TSF is to decompose the total reference torque into phase-specific reference torques according to the rotor position, which are then used as control inputs [21], [22]. The reference torque of each phase, T_k^* in equation (15), is obtained by appropriately shifting the TSF. Based on the torque profile within the commutation overlap region, TSFs can be classified into various types, including linear, exponential, cubic, sinusoidal, and cosine functions. Figure 9 illustrates the torque profiles and corresponding current waveforms for linear and cosine TSFs [23].

$$T_k^*(\theta) = \begin{cases} 0 & 0 \leq \theta \leq \theta_{on} \\ T^* \cdot f_{rise}(\theta) & \theta_{on} < \theta < \theta_{on} + \theta_{ov} \\ T^* & \theta_{on} + \theta_{ov} \leq \theta \leq \theta_{off} - \theta_{ov} \\ T^* \cdot f_{fall}(\theta) & \theta_{off} - \theta_{ov} < \theta < \theta_{off} \\ 0 & \theta_{off} \leq \theta \leq \tau \end{cases} \quad (15)$$

In equation (15), $T_k^*(\theta)$ denotes the total reference torque, f_{rise} defines the slope of the rising phase of the input phase, and f_{fall} is the slope of the falling phase of the output phase. The angles θ_{on} , θ_{off} , and θ_{ov} correspond the turn-on, turn-off, and overlapping positions, respectively, and τ represents the rotor angle period. The relationship between f_{rise} and f_{fall} is given by [20], [24]:

$$f_{fall}(\theta) = 1 - f_{rise}(\theta - \varepsilon) \quad (16)$$

The number of TSF parameters can be reduced to two, as angles θ_{on} , θ_{off} , and θ_{ov} are interrelated as follows:

$$\theta_{off} = \theta_{on} + \theta_{ov} + \varepsilon \quad (17)$$

Here, $\varepsilon = 2\pi/(m \text{ Nr})$ denotes the stroke angle, or angular displacement between adjacent phases, with Nr representing the number of rotor poles. The maximal overlap angle $\theta_{ov,max} = \tau/4$, occurs when the turn-on angle is minimized ($\theta_{on} = \theta_u$) and the turn-off angle is maximized ($\theta_{off} = \theta_{al}$). For instance, in an 8/6 four-phase SRM, the overlap angle is limited to $\theta_{ov,max} = 15^\circ$ since $\tau = 60^\circ$. At any rotor position, two phases' windings are energized simultaneously due to the stroke angle $\varepsilon = 15^\circ$. However, the second constraint $\theta_{ov} \leq \tau/2 - \varepsilon$, derived from this relationship, can be more restrictive for certain motor configurations [9].

$$f_{rise}(\theta) = \frac{\theta - \theta_{on}}{\theta_{ov}} \quad (18)$$

And:

$$f_{fall}(\theta) = 1 - f_{rise}(\theta - \varepsilon) \quad (19)$$

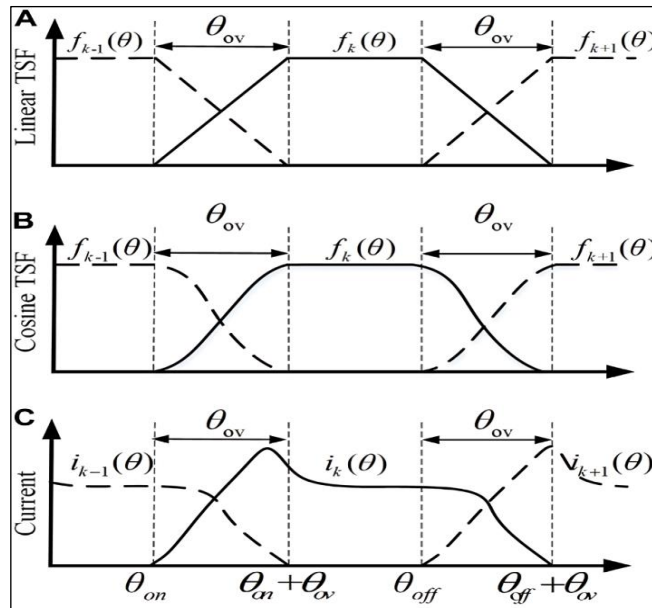


Figure 9: Profiles and current diagrams of linear and cosine TSF functions. (A): Profiles of linear TSF. (B): Profiles of cosine TSF. (C): Diagram of phase current and rotor position.

Source: Authors, (2026).

IV.1 THE PROPOSED STRATEGY

This paper presents a novel Torque Sharing Function method for reducing torque ripple in SRMs. The total reference torque is subdivided into several subintervals ranging from zero to different nonzero values. These subintervals are assigned to phase torques during excitation modes sequentially, prior to shifting excitation to the next phase. The region where two or more phases overlap during excitation is defined as the overlap region. The influence of the overlap angle θ_{ov} on motor performance is investigated.

- A large θ_{ov} smooths the torque waveform but results in energy loss, whereas a smaller θ_{ov} enhances energy efficiency at the expense of higher torque ripple. This method involves the systematic optimization of the overlap angle, defined as the angular difference between the turn-on and turn-off firing angles. The overlap angle is analytically derived with respect to two critical switching angles by evaluating coefficient parameters that characterize the hyperbolic profile of the proposed TSF. These parameters delineate the commutation intervals spanning from T_1 to T_4 thereby precisely shaping the commutation trajectory and modulating the torque distribution. This refined control methodology effectively reduces torque ripple and enhances the dynamic performance in SRM drives. The corresponding control relationship can be expressed by the following equation:

$$f(k) = \begin{cases} \frac{\theta - T_1}{T_2 - T_1} & \text{if } T_1 < \theta < T_2 \\ 1 & \text{if } T_2 \leq \theta \leq T_3 \\ \frac{\theta - T_4}{T_3 - T_4} & \text{if } T_3 \leq \theta \leq T_4 \\ 0 & \text{other} \end{cases} \quad (20)$$

Where:

$$\begin{aligned} T_1 &= \theta_{on} + a \\ T_2 &= \theta_{on} + b \\ T_3 &= \theta_{off} + c \\ T_4 &= \theta_{off} + d \end{aligned} \quad (21)$$

The various configurations of the suggested TSF approach are depicted in figure 10. In order to find the optimal torque shape, which will be the main factor in reducing the ripple of the torque generated as well as the vibrations produced by the machine, the torque generated at every turn depends on the values of all of the coefficients that will be assigned by the optimization algorithm.

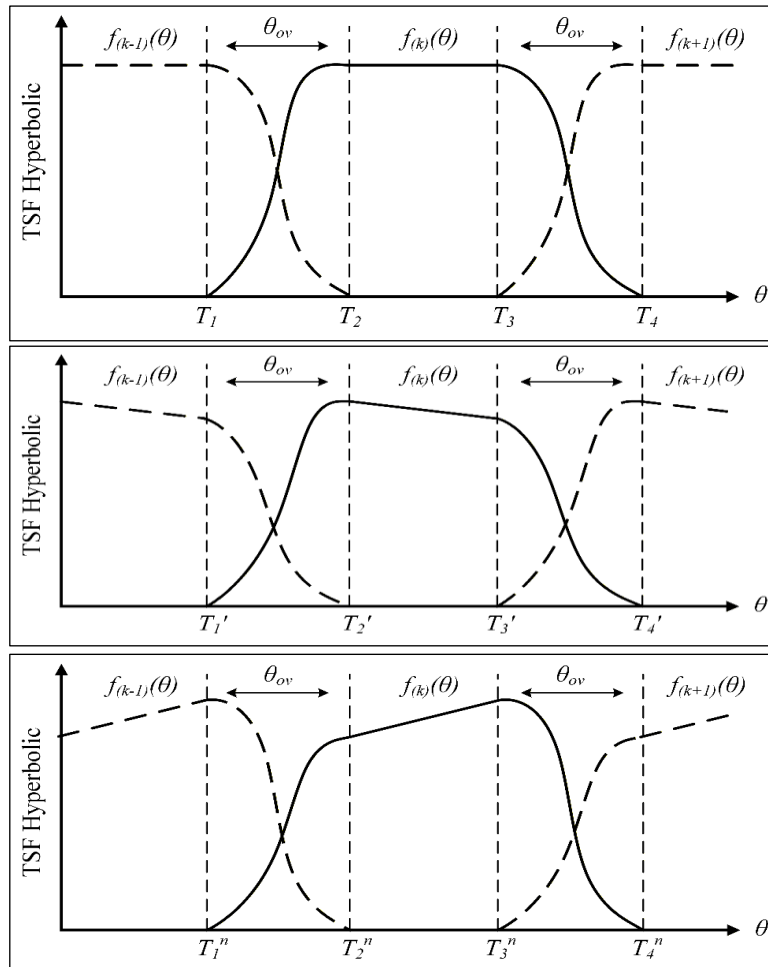


Figure 10: Profiles diagrams of Proposed TSF function.

Source: Authors, (2026).

Simulation studies and parameter optimizations were conducted to determine optimal coefficient values, demonstrating effective reduction in torque ripple and improved SRM performance. This method can be adapted to various SRM configurations for enhanced control precision and efficiency. Compared to conventional linear and cosine torque sharing functions, the proposed optimized TSF demonstrates a substantial reduction in torque ripple under identical operating conditions, confirming its superior capability to manage phase overlap and electromagnetic torque continuity in SRM drives which are represented on Table 1.

V. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO), inspired by natural phenomena, is a computational technique within the field of swarm intelligence. Originally introduced by Kennedy and Eberhart in 1995, PSO simulates the collective behaviour of swarming species, such as birds or fish, as they move toward a target. The algorithm employs a population of particles, each representing a potential solution, which explore the search space to identify the global optimum. During this process, each particle updates its position by considering both its individual best location and the overall best position found by the swarm. In this study, the particle positions represent the PI controller gains and the TSF coefficients a , b , c , and d , along with θ_{on} and θ_{off} , which are iteratively optimized using the mathematical formulations given in Equations (20) and (21) [10]:

$$V_i^{t+1} = wV_i^t + c_1R_{1i}(p_{i,best}^t - x_i^t) + c_2R_{2i}(G_{best}^t - x_i^t) \quad (22)$$

$$X_i^{t+1} = wV_i^{t+1} + X_i^t \quad (23)$$

Where, V_i^{t+1} and V_i^t indicate the velocity of each particle at the current and previous iteration, respectively, while X_i^t and X_i^{t+1} denote the particle positions in the current and previous iterations, respectively. $p_{i,best}^t$ and G_{best}^t represent the personal and global best of each candidate and the whole swarm, and c_1, c_2 and w are the inertia weight, the personal and global learning coefficient, and $R_{1,2}$ is a random number. The flowchart for the procedure is shown in figure 11 [10]. The chosen goal function is the normalized torque ripple factor (TRF) in equation (24), defined as the ratio of the peak-to-peak torque variance to its average value across an electrical cycle, is selected as the objective function. The benefit of this dimensionless formulation is that it is directly related to the vibration excitations of the stator and is independent of the load level. Therefore, as in figure 12, minimizing the TRF is a pertinent criterion that is frequently used in the literature to assess SRMs' vibro-acoustic performance.

$$TRF = \frac{T_{max} - T_{min}}{T_{avg}} \quad (24)$$

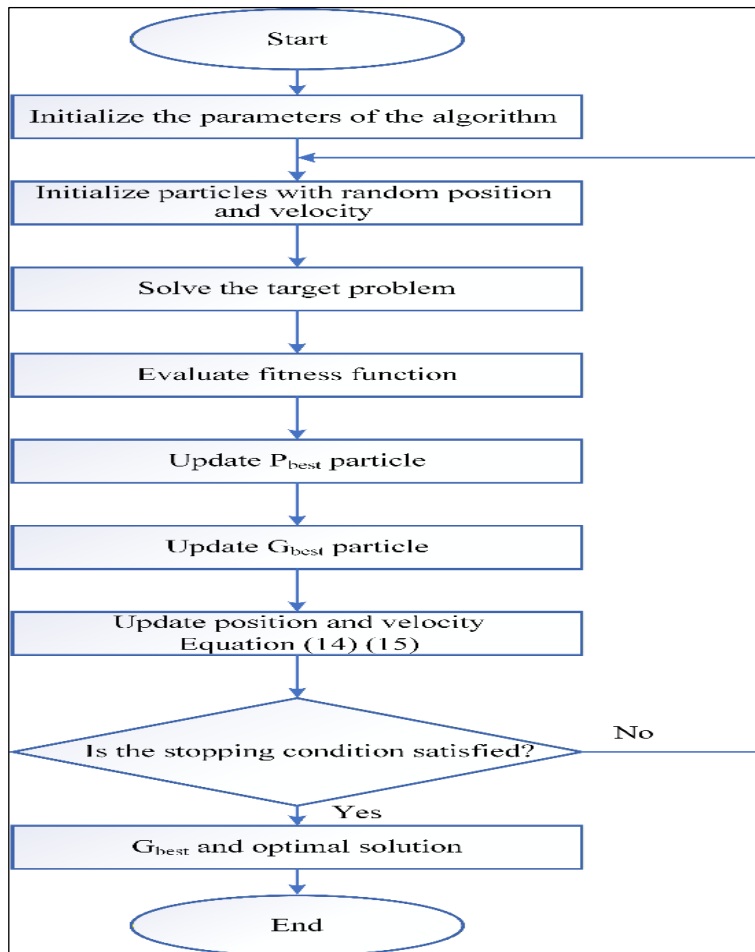


Figure 11: PSO algorithm flowchart.
Source: Authors, (2026).

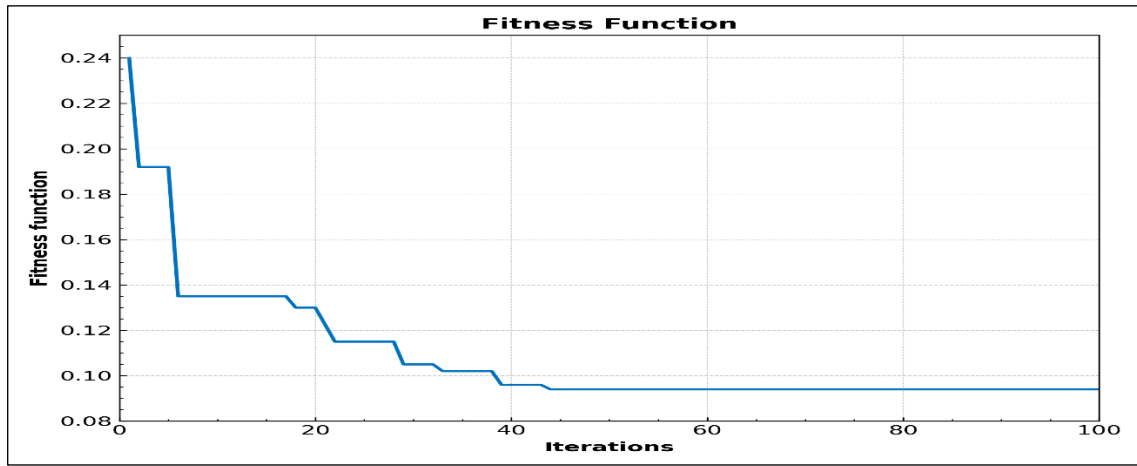


Figure 12: Best fitness of PSO.

Source: Authors, (2026).

VI. RESULTS AND DISCUSSIONS

Torque Sharing Function is a well-established technique aimed at reducing torque ripples in switched reluctance motors. To evaluate the effectiveness of the newly proposed optimization method for torque ripple reduction, TSF was implemented both with and without optimization on a 6/8 SRM under various operating conditions. The simulation involved two load torque scenarios at different speeds: case (1) is 7 N.m at 500 rpm and case (2) is 5 N.m at 1000 rpm. For the case (1) the total torque, phase torque, and current waveforms (illustrated in figures (13), (14), and (15) respectively), indicate that prior to optimization the torque ripple was 42.85% with a turn-on angle (T_{on}) of 2.7° and a turn-off angle (T_{off}) of 22.5° . Following optimization, these parameters were refined to $T_{on} = 0.2^\circ$ and $T_{off} = 23.4^\circ$, resulting in a reduced torque ripple of 14.28%. Correspondingly, the current and phase torque waveforms demonstrate smoother profiles after optimization, reflecting improved control and reduced phase switching.

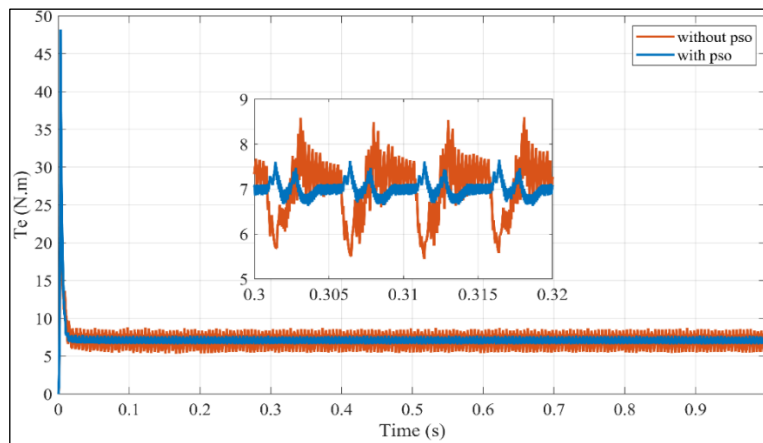


Figure 13: Total torque waveform of the 6/8 SRM under a load torque of 7 N.m at 500 rpm: Without Optimisation and with optimisation.

Source: Authors, (2026).

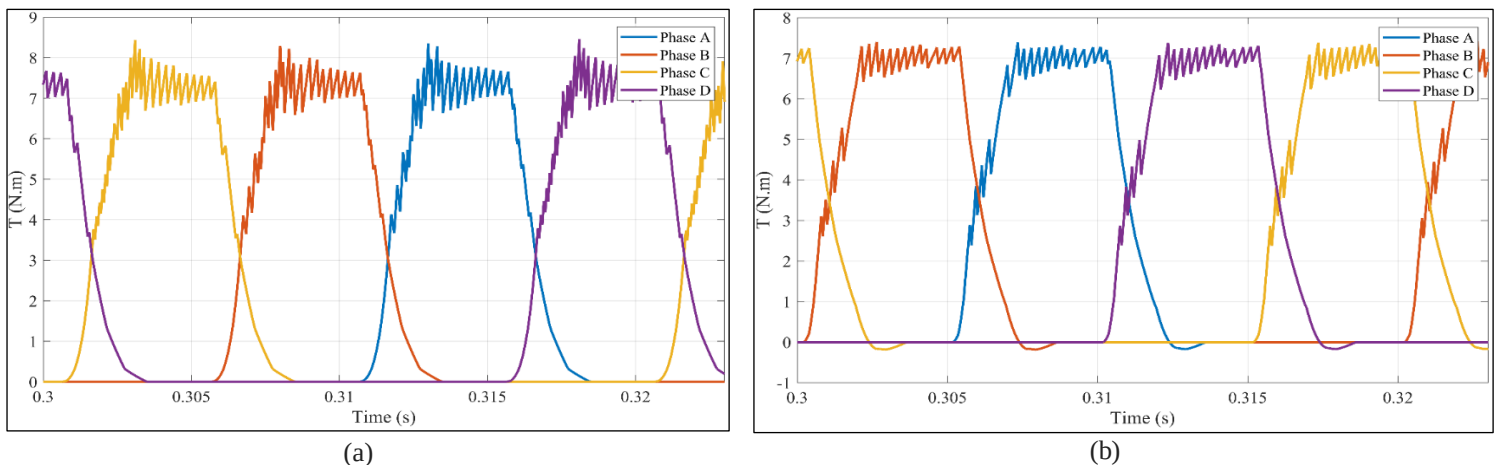


Figure 14: Phase torque waveform :(A) Without Optimisation, (B) with optimisation.

Source: Authors, (2026).

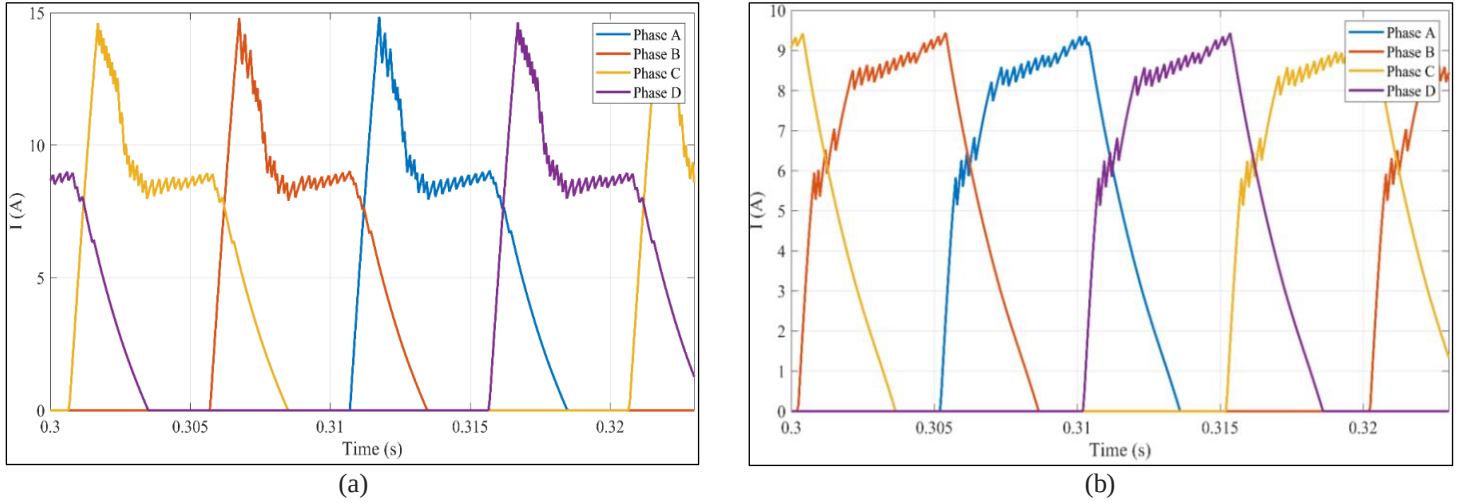


Figure 15: Phase Current profile :(A) Without Optimisation, (B) with optimisation.
Source: Authors, (2026).

Similarly, for the case (2) illustrated on figure (16) the simulations show a torque ripple decrease from 42% ($T_{on} = 5^\circ$, $T_{off} = 22^\circ$) to 20% after optimization ($T_{on} = 0.26^\circ$, $T_{off} = 22.5^\circ$). These improvements in torque ripple, along with smoother current waveforms, underscore the efficacy of the proposed TSF optimization method in enhancing SRM performance under varying load and speed conditions. Figure (17) and (18) demonstrate Phase Torque waveform and Phase Current profile respectively. This optimized TSF approach advances motor control by systematically adjusting switching angles to minimize torque fluctuations and improve operational smoothness, which is critical for applications requiring high precision and reliability.

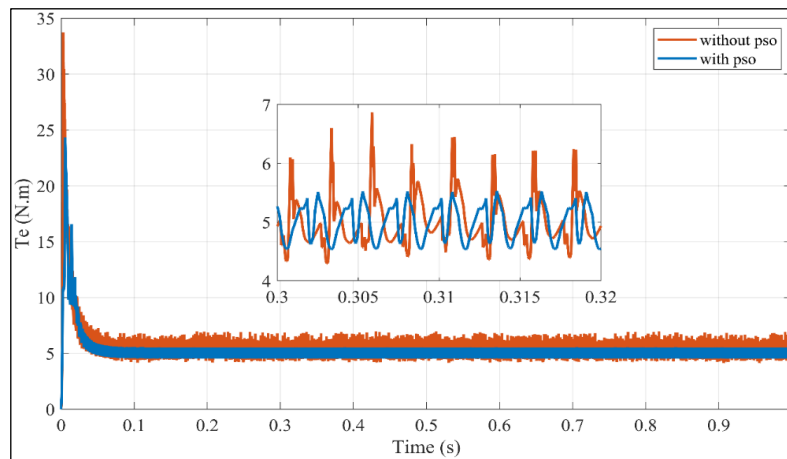


Figure 16: Total Torque waveform of the 6/8 SRM under a load torque of 5 N.m at 1000 rpm: Without Optimisation and with optimisation.
Source: Authors, (2026).

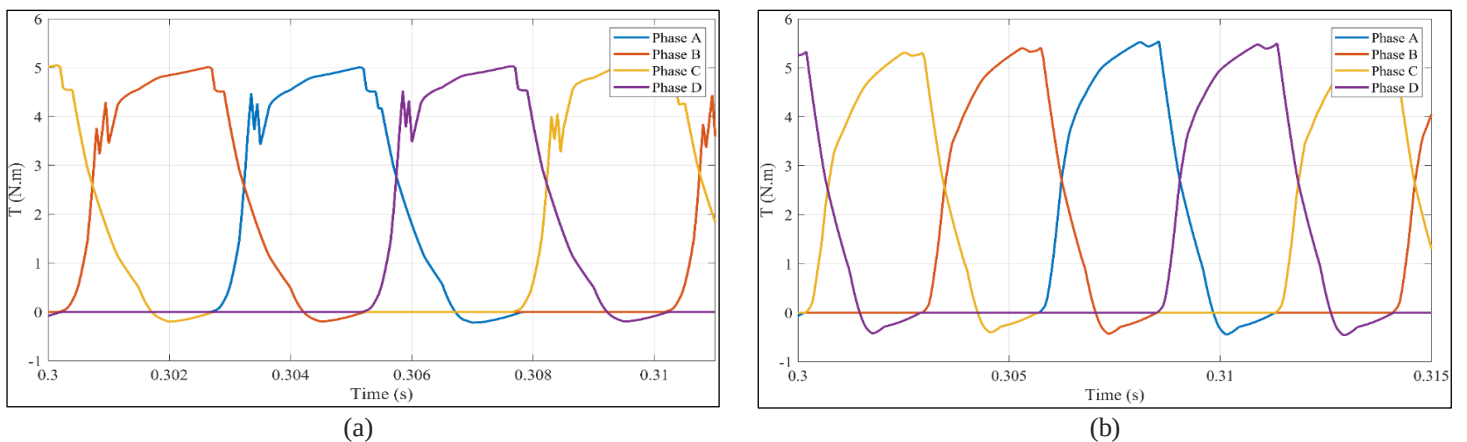
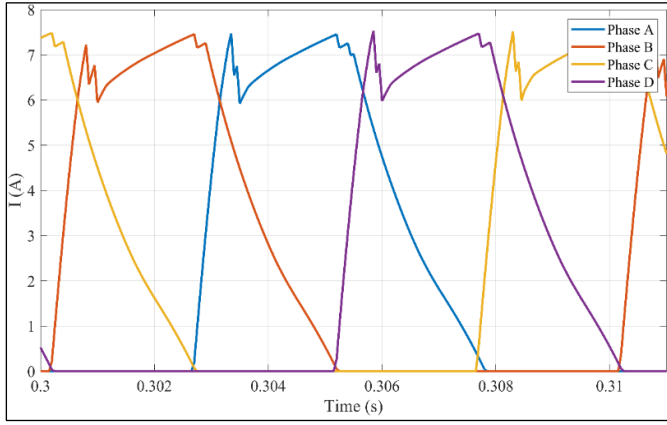
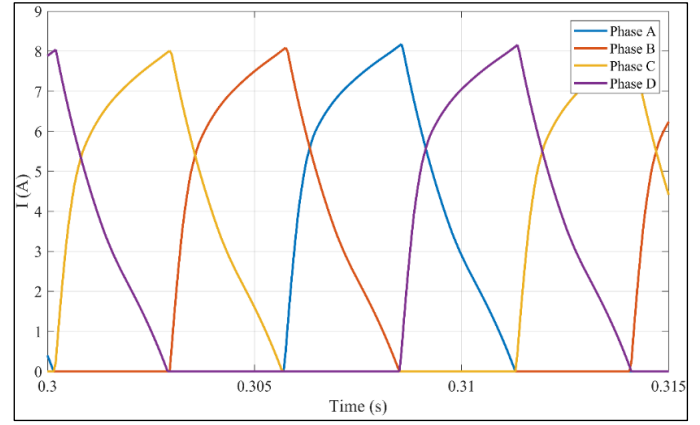


Figure 17: Phase Torque waveform :(A) Without Optimisation, (B) with optimisation.
Source: Authors, (2026).



(a)



(b)

Figure 18: Phase Current profile :(A) Without Optimisation, (B) with optimisation.

Source: Authors, (2026).

Table 1: A detailed comparative evaluation of linear, cosine, and optimized TSF control strategies for SRM.

TSF Strategy	Turn-on Angle Ton		Turn-off Angle Toff		Torque Ripple	
	7 N.m 500 rpm	5 N.m 1000 rpm	7 N.m 500 rpm	5 N.m 1000 rpm	7 N.m 500 rpm	5 N.m 1000 rpm
Linear TSF	3.0	5.0	22.0	22.0	38 %	45–48 %
Cosine TSF	2.5	3.8	22.8	22.5	28 %	24–26 %
Proposed Optimized TSF	0.2	0.26	23.4	22.5	14.28 %	20 %

Source: Authors, (2026).

VII. CONCLUSION

This study proposes a novel hyperbolic Torque Sharing Function (TSF) framework that incorporates the optimization of phase commutation angles to enhance TSF efficacy. The switched reluctance motor (SRM) model was developed with high fidelity using ANSYS to accurately represent electromagnetic behaviours. The control methodology focuses exclusively on torque regulation through overlap angle optimization. By dynamically adjusting the TSF, the approach exploits the disparity in torque production capabilities between commutating phases. Simulation results obtained via MATLAB Simulink confirm a substantial reduction in torque ripple alongside improved system robustness and dynamic response. The validity of the method is corroborated by advanced optimization techniques, and its generalizability ensures applicability across diverse SRM configurations.

VIII. APPENDIX

Table 2: Dimensions and electrical parameters of SRM.

Parameters	Notation	Dimensions	
Effective length	L	170mm	
Outer stator radius	R_{so}	100 mm	
Inner radius of stator yoke	R_{sy}	88.2mm	
Inner stator radius	R_{si}	58.19 mm	
Outer rotor radius	R_{ro}	57.83mm	
Outer radius of rotor yoke	R_{ry}	40.4mm	
Shaft radius	R_{ri}	25mm	
Stator pole arc	β_s	19.70°	20mm
Rotor polar arc	β_r	19.82°	20mm
Air gap thickness	E	0.36 mm	
Number of coils per pole -pair	N_s	180	
Section coil	S	3400mm ²	

Source: Authors, (2026).

IX. AUTHOR'S CONTRIBUTION

Conceptualization: Houda Fetoui, Chouaib Labiod.

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Writing – Original Draft: Houda Fetoui.

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